BUILDING PANEL HAVING AT LEAST TWO PANEL DOMAINS OF DIFFERENT AVERAGE COMPRESSIVE STRENGTH

CROSS REFERENCE STATEMENT

This application claims the benefit of U.S. Provisional Application No. 60/266,112, filed February 2, 2001.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a building panel having at least two panel domains of different average compressive strengths. The panel is useful for filling cavities having non-uniform dimensions, having obstacles disposed therein, or both.

Description of Related Art

Building structures typically contain a framework defining a plurality of cavities with the framework acting as cavity walls. For instance, buildings often have a wood or metal framework comprised of studs and joists spaced a certain distance apart. The studs and joists act as cavity walls. A distance between two studs or joists defines a cavity spacing and a volume between two studs or two joists defines a cavity. It is often desirous to insert within a cavity a material, such as a thermal insulator. However, cavities come in a variety of sizes and shapes and may have obstacles, such as electrical conduit or plumbing pipes, disposed therein. Fitting panels tightly into cavities of varying dimensions and containing a variety of obstacles requires either manufacturing a specific panel for each different cavity or the use of a panel that is sufficiently flexible to conform to different cavity sizes, shapes and obstacles.

Common materials for filling cavities include fibrous materials and polymeric foam. Fibrous materials, such as glass wool and cellulose fiber, typically require special care during installation since inhalation and handling of

fibers is often irritating. Fibrous batting is also especially flexible, allowing the batting to buckle, sag, or droop when spanning a wide cavity such as between rafter joists. Rigid polymeric foam, such as polystyrene (PS) and rigid polyurethane foam, is attractive as thermal insulation in cavities, but performs less than optimally in conforming to various cavity sizes, shapes and obstacles. Rigid polymeric foam typically requires cutting to conform to a specific cavity. Flexible polymeric foam, such as flexible polyurethane foam (FPU), conforms more readily to cavity variations than a rigid foam board. Unfortunately, the flexibility also allows the foam to buckle, sag or droop when spanning a wide cavity such as between rafter joists.

Ideally, a panel for fitting into cavities has a combination of flexible properties for conforming to cavity shapes, sizes and obstacles and rigid properties to hinder buckling and sagging of the panel when disposed within a cavity. United States patent application 09/706,110 ('110) discloses one such panel comprising a combination of hollow and solid coalesced foam strands (*see*, page 14 lines 7-17, incorporated herein by reference).

A need exists for a panel that can fit into cavities having various sizes, shapes and obstacles yet does not suffer from handicaps attributed to fibrous materials, rigid foam, or flexible polymeric foam and which is free of a combination of hollow and solid foam strands.

BRIEF SUMMARY OF THE INVENTION

In a first aspect, the present invention is a building panel comprising at least two panel domains, wherein each panel domain has an essentially homogeneous compressive strength and an average compressive strength; wherein said panel: (a) has at least two panel domains having different average compressive strengths; and (b) is essentially free of a combination of hollow and solid foam strands; and wherein,

if said panel has at least two adjacent panel domains containing fibrous material with a fiber orientation, the fiber orientation of one panel domain is non-orthogonal to the fiber orientation of at least one adjacent panel domain.

A particularly useful variation of the first aspect comprises at least one conformable panel domain that, when compressed, reduces at least one dimension of the panel thereby allowing insertion of the panel into a cavity; wherein the panel has a compressive recovery that causes frictional retention of the panel within the cavity. That is, the conformable panel domain presses against a cavity wall of a cavity with sufficient pressure to retain the building panel within the cavity due to friction between the cavity wall and conformable panel.

Another useful variation of the first aspect contains a conformable panel domain within the panel; wherein said conformable panel domain allows the panel to reversibly bend from a planar to a non-planar configuration.

In a second aspect, the present invention is a method for at least partially filling a cavity comprising inserting at least one panel within the cavity, wherein at least one inserted panel is the panel of the first aspect.

The present invention meets a need by providing a panel that can fit into cavities having various sizes, shapes and obstacles yet does not suffer from handicaps attributed to fibrous materials, rigid foam, or flexible polymeric foam and which is free of hollow and solid foam stands.

BRIEF DESCRIPTION OF DRAWINGS

Figure (FIG) 1 shows a panel comprising two panel domains.

FIGs 2a, 2b, and 2c show an example of a panel inserting into a cavity by reversibly bending from a planar into a non-planar configuration.

FIG 3a shows a panel having a conformable panel domain around the perimeter of the panel.

FIG 3b shows a panel having multiple conformable panel domains around the perimeter of the panel.

FIGs 4a and 4b show an end-on view of two panels, one with a tongue profile and another with a groove profile, connectively inserting into a cavity.

FIGs 5a and 5b show a panel of the present invention working together with a panel having a single panel domain to span a cavity.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a building panel. A "building panel" refers to a single article useful in fabricating buildings and structures containing cavities. Herein, "building panel" and "panel" are interchangeable.

A building panel can be any shape or dimension that has two opposing surfaces, at least one of which is a "primary face". The primary face of a building panel has a surface area equal to that of the highest surface area face on the panel. A building panel may have two primary faces as long as they are opposing and not adjoining. A primary face is desirably a square or rectangle, although it may be any shape, including circular. Building panels having a square or rectangular primary face are square or rectangular building panels, respectively. Preferably, a primary face is parallel to its opposing face. The face or faces joining a primary face to its opposing face are minor faces, forming a perimeter around the building panel. Examples of minor faces include opposing ends and opposing edges of a square or rectangular building panel.

"Panel thickness" is a perpendicular distance between a primary face and its opposing face. The panel thickness at any point on a primary surface of the building panel is preferably one centimeter (cm) or greater, more preferably 2

cm or greater and may be 5 cm or greater, 10 cm or greater, even 20 cm or greater. There is no known functional limit as to how thick a building panel may be. Building panels having a panel thickness less than one cm tend to be too thin to span a cavity width without buckling, sagging, or both.

A building panel may have contours on one or more surface. For example, a primary surface may have a decorative design or a functional contour, such as cone-like protrusions for acoustical attenuation. The building panel may include grooves to facilitate conforming around obstacles within a cavity or to facilitate bending of the panel.

Building panels desirably, though not necessarily, have an essentially uniform panel thickness. Herein, a building panel has an essentially uniform panel thickness if a difference in panel thickness at any two points on a primary surface of a building panel is less than 10% of an average of the panel thickness at those two points or 5 millimeters (mm), whichever is greater. Preferably, the building panel has a panel thickness difference of less than 3 mm, more preferably less than 2 mm between any two points in the building panel.

A building panel of the present invention further comprises at least two panel domains. A "panel domain" is a section of a building panel that extends a building panel's length, width, thickness, or a combination thereof. A panel domain typically contains at least 1%, preferably at least 2%, more preferably at least 5%, still more preferably at least 10% and less than 100% of a building panel's volume. Examples of suitable panel domains include bands, strips, plugs (such as cylindrical plugs extending the thickness of a building panel) or a combination thereof. Preferably, panel domains are "bands". Bands are panel domains that traverse a primary face of a building panel. Desirably, a band also extends the thickness of the panel. For example, a band may extend through the panel thickness and extend to opposing

ends (the length) of a rectangular building panel. Panel domains may have any shape and size and may differ in size, shape and physical properties within a building panel. Preferably, at least one panel domain, more preferably at least two panel domains, more preferably all panel domains in a building panel have a thermal conductivity of 0.1 Watt per meter-Kelvin (W/m*K) or less, more desirably 0.065 W/m*K or less, most desirably 0.045 W/m*K or less. Determine thermal conductivity according to ASTM method C-518-98.

Each panel domain has an essentially homogeneous compressive strength and an average compressive strength. "Essentially homogeneous compressive strength" means that any section of the panel domain containing 20% of the panel domain volume has an average compressive strength in any direction within 20%, preferably within 10% of any other section of similar dimensions of the panel domain containing 20% of the panel domain volume that is compressed in the same direction and orientation. Measure compressive strength values according to American Society for Testing and Materials (ASTM) method D1621 unless otherwise noted. "Average compressive strength" is the average compressive strength over a compression range of 0-50%, more preferably over a compression range of 0-80%. Herein, ranges include boundary values unless otherwise stated.

Panel domains may be made of wood, metal, glass, rubber, fibrous materials, inorganic foams, organic foams, and combinations thereof.

Examples of fibrous materials include fiber batting, glass wool, mineral wool, polymeric fiber batting, carbonaceous fibers, and rock wool. Building panels may comprise at least two adjacent domains containing fibrous material provided that if the fibrous material has a fiber orientation, the fiber orientation of one domain is non-orthogonal to the fiber orientation in at least one adjacent domain. For example, United States Patent 4,025,680

discloses a fibrous thermal insulation comprising a plurality of abutting parallel strips of fiber with the fiber orientation in the strips alternating at right angles in the adjacent strips (*see*, column 2 lines 5-11, incorporated herein by reference). Such a material is not within the scope of the present invention since the fiber orientation of each strip (or panel domain) is at a right angle (orthogonal) to the fiber orientation of each adjacent strip.

Preferably, at least one panel domain is free of fibrous materials, more preferably the entire building panel is free of fibrous materials. Still more preferably, at least one panel domain is a polymeric foam; most preferably all panel domains in a building panel comprise polymeric foam.

Suitable polymeric foams include those containing one or more of the following: polystyrene (PS) polymers and copolymers; polyesters, polyolefins such as polyethylene (PE), polypropylene (PP), PE copolymers such as ethylene/styrene interpolymers (ESI), and PP copolymers; and polyurethane. Polymeric foams can contain a blend of polymers, such as PP and PE blends.

Polymeric foams preferably have a density of 100 kilograms per cubic meter (kg/m^3) or less, more preferably 50 kg/m^3 or less. Foams having a density of greater than 100 kg/m^3 generally have undesirable thermal insulating properties. Foams generally have a density greater than 5 kg/m^3.

Polymeric foams have an average cell diameter. Determine average cell diameter by measuring cell diameters on a cross-section of a foam. The average cell diameter for the foam is an average diameter for 20 or more randomly selected cell cross-sections on the foam cross-section. The diameter of non-spherical cells is the average of the longest and shortest chord through the center of the cell cross-section. View the foam cross-section using optical or electron microscopy. Polymeric foams useful in this

invention preferably have an average cell diameter of 0.01 mm or greater, more preferably 0.1 mm or greater, still more preferably, 0.3 mm or greater. Preferably, the average cell diameter is 10 mm or less, more preferably 4 mm or less, still more preferably 2 mm or less. A foam that has an average cell diameter below 0.01 mm tends to have an undesirably high density. A foam that has an average cell diameter greater than 10 mm tends to be a poor thermal insulator.

Building panels of the present invention comprise at least two panel domains that have differ in average compressive strength. Measure compressive strength with similar panel domain sections that are of similar size and shape and by compressing in the same direction and orientation. Preferably, the two panel domains differ in average compressive strength when compressed in a dimension corresponding to a building panel's width. Desirably, the two panel domains differ in average compressive strength by at least 5%, preferably at least 10%, more preferably at least 25%, and can differ in average compressive strength by 50% or more, 100% or more, even 200% or more.

Desirably, at least one panel domain is conformable. A conformable panel domain is compressible and resilient, thereby imparting a compressibility and compressive recovery to the building panel. A conformable panel domain is advantageously smaller in the dimension of compression than any other dimension so as to hinder buckling of the panel domain during compression.

Compressibility at 10% compression characterizes the compressibility of a panel domain. A conformable panel domain preferably has a compressive strength at 10% compression of 0.1 kiloPascals (kPa) or more, more preferably 0.2 kPa or more, and still more preferably 0.3 kPa or more and 200 kPa or less, more preferably 50 kPa or less, still more preferably 20 kPa or less. A panel domain having a

compressive strength less than 0.1 kPa typically lacks sufficient durability while a panel domain having compressive strength greater than 200 kPa is generally too difficult to compress.

Percent recovery from 50% compression characterizes the resiliency of a panel domain. Measure percent recovery by applying a compressive force to a panel domain sufficient to compress the panel domain to 50% of its non-compressed thickness. Relieve the compressive force and measure the panel domain thickness after 24 hours. The panel domain thickness 24 hours after relieving the compressive force divided by the uncompressed thickness of the panel domain is the compressive recovery for the panel domain. A conformable panel domain preferably has a compressive recovery of 60% or more, more preferably 70% or more, still more preferably 80% or more.

Preferably, compressing at least one conformable panel domain in a building panel reduces at least one dimension of the building panel. Reducing a dimension of a building panel can allow insertion of the building panel into, for example, a cavity having a width less than the uncompressed dimension of the building panel.

More preferably, the building panel has a compressive recovery when no longer compressing the conformable panel domain(s). The compressive recovery of a building panel desirably supplies sufficient pressure against cavity walls to frictionally retain the building panel within a cavity. Generally, the compressive recovery will cause a building panel to apply a pressure of 100 Newtons-per-square-meter (N/m^2) or more, preferably 200 N/m^2 or more, more preferably 300 N/m^2 or more. A pressure of less than 100 N/m^2 is generally insufficient to frictionally retain a building panel within a cavity without buckling or sagging. Usually, the pressure is 200,000 N/m^2 or less, preferably 50,000 N/m^2 or less, more preferably 30,000 N/m^2 or less. Building panels

that apply a pressure greater than 200,000 N/m^2 are typically very difficult to compress.

Suitable conformable panel domains include polymeric foam and fibrous materials such as fiber batting, glasswool, carbonaceous fiber, and mineral wool. Preferably, the conformable panel domain is a polymeric foam, more preferably an open-celled polymeric foam. Foams for use in conformable panel domains desirably have an open cell content of 5% or more, more desirably 10% or more, still more desirably 30% or more, and most desirably 50% or more, according to ASTM method D2856-A. A polymeric foam having less than 5% open cell content often lacks a desirable compressibility.

Adjacent panel domains within a building panel may have distinct, gradient, or variable boundaries. Two adjacent panel domains have a distinct boundary when at least one building panel property, such as compressive strength or density, abruptly changes from that of one panel domain to that of another panel domain. An abrupt change is one occurring in a distance of 0.5 cm or less, preferably 0.2 cm or less, more preferably 0.1 cm or less. For example, gluing two pieces of polymeric foam having different compressive strengths together along adjacent edges can create a building panel having two panel domains and a distinct boundary between those panel domains. Distinct boundaries separating panel domains by greater than 0.5 cm tend to become gradient boundaries or variable boundaries, or even another panel domain.

Alternatively, two panel domains may have a gradient boundary where at least one property is either in between that of each individual panel domain or gradually changes from that of one panel domain to that of an adjacent panel domain. For example, extruding two foams having different densities such that they blend together at an interface can produce a building panel having a gradient boundary that gradually changes from the density of one panel domain to

that of the adjacent panel domain. The interface between two panel domains connected with a lap joint would also constitute a gradient boundary.

Two panel domains may instead have a variable boundary where at least one building panel property is variable but not steadily changing across the boundary from that of one panel domain to that of the other.

One variation of the present invention is a square or rectangular building panel having bands. Bands preferably traverse the largest dimension of a primary face (the building panel length) and that of its opposing face. Bands may extend orthogonally from one end of the building panel to an opposing end, traverse the building panel diagonally such as from one corner to an opposing corner, or may extend from one end to another in a non-linear shape. Bands can be any shape and size, though they preferably are thicker than they are wide to prevent buckling during compression.

One desirable building panel configuration contains a conformable band along at least one edge of a square or rectangular building panel. Such a band is a "conformable edge band". Conformable edge bands allow the building panel to conform to obstacles, such as conduit and plumbing pipes, along cavity walls. Another beneficial building panel configuration comprises conformable panel domains along the ends of the building panel that can fit to obstacles that extend across the end of the building panel within a cavity. A building panel, be it square, rectangular or some other shape, may have a perimeter comprising one or more conformable panel domains.

Another variation of the square or rectangular building panel comprises at least one conformable band within the building panel that allows the building panel to bend into a non-planar configuration, facilitating insertion into a cavity.

One desirable panel domain configuration for the building panels of the present invention has alternating conformable and rigid panel domains, or alternating rigid and conformable bands. A rigid panel domain is a panel domain having a higher average compressive strength than any adjoining conformable panel domain. For example, a square or rectangular building panel may have alternating rigid and conformable bands. FIGs 1, 2a, 2b, and 2c show examples of building panels having alternating conformable and rigid panel domains.

FIG 1 shows an example of a building panel 10 having a panel thickness T and comprising two panel domains, 20 and 30. Panel domains 20 and 30 are bands within building panel 10. Panel domain 20 has a higher average compressive strength than panel domain 30. A primary face 15 of building panel 10 comprises faces 22 and 32, respectively, of panel domains 20 and 30. FIG 1 shows an interface 40 between panel domains 20 and 30 as a variable boundary. FIG 1 shows an edge 12 of building panel 10, which also serves as an edge of panel domain 30. Building panel 10 has a length L equaling that of panel domain 30. Building panel 10 has width W.

FIGs 2a, 2b and 2c show an example of a building panel 50 having five panel domains 60, 70, 80, 90, and 100. All five panel domains are bands of building panel 50. Panel domains 60, 80, and 100 are conformable. Panel domain 80 allows building panel 50 to bend into a non-planar configuration. FIG 2a shows building panel 50 and cavity 115. The width W' of building panel 50 is larger than the spacing between cavity walls 110 and 120, which define cavity 115. FIG 2b shows building panel 50 after bending into a non-planar configuration for insertion into cavity 115. Applying force F against panel domain 80 returns building panel 50 into a planar configuration within cavity 115, compressing panel domains 60, 80, and 100. FIG 2c shows building panel 50 within cavity 115.

Building panels of the present invention may include at least one slit traversing a primary face or a face opposing a primary face and extending to a depth less than the panel thickness. Such slits facilitate bending a building panel into a non-planar configuration for insertion into a cavity. FIGs 2a, 2b, and 2c also show such an optional slit 82 in panel domain 80. FIG 2b shows slit 82 open slightly when building panel 50 bends into a non-planar configuration, thereby facilitating the bending of building panel 50.

FIG 3a shows a building panel 130 with two panel domains 132 and 134. Panel domain 134 is a conformable panel domain disposed around the perimeter of building panel 130. FIG 3a shows panel domain 134 as a single piece, but it may also consist of multiple pieces. FIG 3b shows a similar building panel 140 having panel domain 142 and multiple conformable panel domains 144, 146, 148, and 150 around the perimeter of building panel 140.

Building panels may have a tongue or a groove profile on at least one minor face. A tongue profile contains a tongue and, preferably, one or two shoulders. Similarly, a groove profile contains a groove and, preferably, one or two shoulders. A tongue on one building panel advantageously fits into a groove on an adjacent building panel to form a joint between building panels. Any tongue and groove shape is feasible, but rounded shapes are beneficial, enabling the tongue of one building panel to roll into the groove of another building panel. Shoulders assist in keeping the tongue of one building panel from moving out of the groove of an adjacent building panel, thereby causing buckling or sagging at the joint between the two building panels. Shoulders, if present, consist of greater than zero %, preferably 5% or more, more preferably 10% or more of the panel thickness and desirably 95% or less, preferably 80% or less and more preferably 60% or less of the panel thickness.

If the shoulders consist of greater than 95% of the panel thickness the tongue tends to easily break.

FIGs 4a and 4b show an end-on view of two building panels 160 and 170, and cavity 185, defined by cavity walls 180 and 190. Building panel 160 comprises a conformable panel domain 162 and a rigid panel domain 163 with a tongue profile comprising a tongue 164 and shoulders 166 and 168. Building panel 170 comprises a conformable panel domain 172 and a rigid panel domain 173 with a groove profile comprising a groove 174 and shoulders 176 and 178. Building panels 160 and 170 connectively insert into cavity 185 by placing conformable panel domains 162 and 172 against cavity walls 180 and 190, respectively, and sliding tongue 164 into groove 174 while applying force F' against rigid panel domains 163 and 173. FIG 4b shows building panels 160 and 170 connectively inserted into cavity 185 with conformable panel domains 162 and 172 compressed slightly.

Generally, when two or more building panels adjoin one another within a cavity, pressure resulting from a compressed panel domain's resiliency is sufficient to hold adjoining building panel together. However, adjoining edges of two adjoining building panels can have an adhesive between them to prevent the building panels from separating. Similarly, applying adhesive tape or any type of fastener along primary faces of adjoining building panels and across adjoining edges can help to prevent the building panels from separating.

One suitable method for preparing building panels of the present invention is by joining together discrete panel domains, such as different pieces of polymeric foam or combinations of polymeric foam and fibrous materials, to form a single building panel. A skilled artisan can identify any of a number of means suitable for joining together two panel domains including double sided tape, epoxy or polyurethane adhesives, latex adhesives, hinges, and wires inserted into and possibly through adjoining panel domains. Melt welding

polymeric panel domains together using heat or solvents is also acceptable.

Another suitable method for preparing building panels of the present invention is by chemically, mechanically, or both chemically and mechanically modifying at least one domain within a building panel initially having an essentially homogeneous compressive strength. For example, buckling or fracturing cell walls or perforating, slicing, or removing portions of a polymeric foam panel domain tends to lower the compressive strength of that panel domain. Slices within a panel domain may be either in a plane or perpendicular to a plane of compression and still lower a compressive strength of the panel domain. Slices in the plane of compression may result in localized buckling of the panel domain. Chemically modifying a panel domain of a polymeric foam also can create panel domains of differing compressive strength. For example, adding a plasticizer to a polymeric foam tends to lower its compressive strength while adding a crosslinker tends to increase the compressive strength of the foam. Chemical and mechanical modifications are also useful for creating domains of differing compressive strengths in building panels that do not have an initially essentially homogeneous compressive strength.

Still another acceptable method for preparing a building panel of the present invention is by simultaneously manufacturing the panel domains in such a manner that adjacent panel domains join during manufacturing. For example, coextruding different polymeric foams through dies adjacent to each other such that, during expansion, the polymer foams contact each other and coalesce at a joint where contact occurs. The different foams then form different panel domains in a polymeric foam building panel.

Similarly, coalesced strand foam technology is acceptable for preparing building panels of the present invention. In fact, coalesced strand foam technology has

unique advantages over other foam technologies in preparing the building panels.

Coalesced strand foam technology involves extruding a foamable gel through a die comprising multiple holes to foam a strand foam. The "strands" extrude through the holes, expand, and bind to one another creating a structure, such as a building panel, comprising multiple foam strands. A foam structure comprising a number of coalesced foam strands is a strand foam. Each strand has a skin and a core. The skin wraps around the core and has a higher density than the core. Stands typically bind together as their skins coalesce during expansion. The use of an adhesive to bind strands together or help assist in binding strands together is also acceptable.

The compressive strength of a strand foam is a function of many parameters. Herein, compressive strength corresponds to compressive strength during radial strand compression when in reference to a strand foam. For example, a strand foam having a given number of strands per cross-sectional area typically has a higher compressive strength than a strand foam having fewer strands per cross-sectional area. One possible reason for a higher compressive strength in the strand foam having more strands per cross-sectional area is that more strands correspond to more skin in a strand foam cross section. The skin establishes a support structure through the strand foam cross section that resists compression.

Interstrand spaces also lower a strand foam's compressive strength. Interstrand spaces form when strands are sufficiently small or spaced sufficiently far apart so that neighboring strands touch one another only periodically while expanding. The places where the strands do not touch remain as voids between strands. These voids are interstrand spaces. Interstrand spaces reduce the compressive strength

of a strand foam by allowing strands to compress into the spaces instead of into a neighboring strand.

An artisan of ordinary skill in the art can identify, without undue experimentation, many ways to prepare strand foams having different compressive strengths.

Modifying a die through which the foam strands extrude can modify many strand foam parameters, including the compressive strength of a strand foam. A die typically has a certain number of holes per unit area. The holes have a certain shape, size, and a certain orientation in the die. For a given foamable gel extruded through the die to form a strand foam, the number of holes per unit area in the die dictates the number of strands per unit cross-sectional area in the resulting strand foam. The hole shape dictates the shape of the foam strands. The hole size dictates the strand size. The hole orientation dictates the interstrand orientation in the strand foam.

Extruding a foamable gel through a die having two or more sections differing in at least one of the following: number of holes per unit area, hole shapes, and hole spacings can create a strand foam having different panel domains. For example, one section of a die may have a specific number of holes per unit area and an adjacent section of the die may have fewer holes per unit area. Expanding a foamable gel through such a die will create a strand foam building panel having one panel domain of a specific number of strands per cross-sectional area adjoined to another panel domain having fewer strands per cross-sectional area. The panel domain having fewer strands per cross-sectional area will have a lower compressive strength than the panel domain having more strands per cross-sectional area.

Foam strands may be solid or hollow. Solid strands have foam through the full cross-section of the strand. Hollow strands have foam only around a circumference of the strand cross-section such that the center of the strand cross-

section does not contain foam. Hollow strands, and their preparation, are further described in United States patent application number 09/706,110 ('110) (*see*, page 2 line 30 through page 5 line 17, incorporated herein by reference). Hollow strands tend to have a lower compressive strength when compressed radially than solid strands. Building panels of the present invention may contain hollow strands or solid strands, but are essentially free of a combination of hollow and solid strands. A building panel is essentially free of a combination of hollow and solid strands if the difference between the number of solid foam strands and the number of hollow foam strands is greater than 90%, preferably greater than 95%, more preferably greater than 98% of the total number of strands.

Polymeric strand foam typically comprises at least one organic polymer for preparing polymeric strand foam. Organic polymers include alkylene aromatic polymers, polyolefins, rubber-modified alkylene aromatic polymers, alkylene aromatic copolymers, hydrogenated alkylene aromatic polymers and copolymers, alpha-olefin homopolymers and copolymers, or blends of the foregoing polymers with a rubber. Preferred polymers include homopolymers and copolymers of PP, PE, and PS, including ESI.

Building panels of the present invention may work in conjunction with building panels outside of the scope of the present invention in order to span a cavity. For example, FIGs 5a and 5b show building panels 220 and 230 working in conjunction to span cavity 205. Building panel 220 contains panel domains 222 and 224. Panel domain 222 is conformable. Building panel 230 contains single panel domain 232 having opposing edges 234 and 236. FIG 5a shows building panels 220 and 230 inserting into cavity 205, with panel domain 222 against cavity wall 200 and edge 234 of panel domain 232 against cavity wall 210. Position edge 226 of building panel 220 against edge 236 of building panel 230 and apply force F″

against edges 226 and 236 to position building panels 220 and 230 into cavity 205. Panel domain 222 compresses as the building panels insert into cavity 205. FIG 5b shows building panels 220 and 230 within cavity 205.

A building panel of the present invention may connect to at least one other building panel, which may or may not be within the scope of this invention, using at least one hinge to create a hinged building panel. A hinged building panel is capable of reversibly bending at the hinge(s) to assume a non-planar configuration for insertion into a cavity. Similarly, at least one panel domain may connect at least one other panel domain via at least one hinge. Suitable hinges include bendable polymer or metal strips, polymer or metal films, or actual devices designed for hingedly connecting structures. Hinges may attach to the primary faces of adjacent building panels or panel domains, attach to minor faces of adjacent building panels or panel domains, or penetrate into adjoining building panels or panel domains. One building panel variation includes a hinge between one or two conformable panel domains where, upon insertion of the building panel into a cavity, the conformable panel domain(s) compresses and conforms around the hinge to tightly contact the panel domain to which it is hingedly connected.

Panel domains, even entire building panels, can include facers on at least one surface, particularly a primary surface. Suitable facers include polymeric films, metal sheets and foils (such as aluminum foil), paper, woven and non-woven materials including glass fiber and cloth, and combinations thereof. Such facers can provide additional air barrier properties to a building panel, can act as a hinge between panel domains, can enhance the decorative nature of the building panel and assist in keeping the building panel from buckling or sagging. Facers can, but need not, cover an entire surface of a building panel.

Many building panel configurations are conceivable within the scope of the present invention. For example, a foam building panel comprising a single foam can have cylindrical plugs of another foam (or some other panel domain material), that has either a higher or lower compressive strength than the foam building panel, disposed through the foam thickness in a specific pattern to direct compression of a foam under pressure. Alternatively, building panels comprising a principal domain material can have tapered or grooved sections that are filled with a domain material other than the principal panel domain material. An artisan can conceive of many different configurations that fall within the scope of the present invention.

Building panels of the present invention are useful as thermal insulation, acoustical attenuators and insulators, decorations, or simply to fill a cavity to, for example, keep insects or rodents from entering the cavity. The building panels are particularly useful for placing within wall and roof cavities in houses, garages and other buildings. The building panels of the present invention are also useful for placing within wall cavities of, for example, portable insulating containers.

The following examples further describe the invention and do not limit the scope in any way. Determine compressive strength (stress) values using European Norm (EN) 826, or as otherwise indicated. Determine thermal conductivity according to EN 28301 at 10°C.

Examples (Ex) 1 and 2. Comparison of Building Panels with and without Conformable Edge Bands

Ex 1 illustrates a building panel of the present invention originating from a single strand foam panel. Ex 1 contains a conformable panel domain that is not along a panel edge.

Ex 2 illustrates a building panel of the present invention similar to Ex 1 that further comprises conformable panel domain on opposing panel edges ("conformable edge bands"). Ex 2 is similar to the panel in FIG 2a and 2b. Ex 2 can conform to larger diameter obstacles on the wall of a cavity than a similar panel free of conformable edge bands, such as Ex 1.

Prepare Ex 1 and Ex 2 using panels of polyolefin-based coalesced strand foam (such as PROPEL™ 12-20 polymeric foam, PROPEL is a trademark of The Dow Chemical Company) 130 cm long, 60 cm wide, and 10 cm thick. Create a conformable panel domain in Ex 1 and Ex 2 by perforating through the foam in a 10 cm wide band through the center of the building panel. Perforate by needle punching using 2 mm diameter needles positioned 5 mm apart along orthogonal axes. Create conformable edge bands on Ex 2 by perforating a panel domain 5 cm wide along the edges of Ex 2, using the same needle punching procedure as when forming the 10 cm wide conformable band. The non-perforated panel domains in Ex 1 and Ex 2 are rigid panel domains. Both Ex 1 and 2 illustrate building panels having panel domains that are bands.

Table 1 shows the compressive strength for the rigid and conformable panel domains of Ex 1 and 2. Percent strain corresponds to percent compression.

Table 1. Compressive Strength in kPa For the Panel Domains in Ex 1 and 2.

Panel Domain	10% Strain	25% strain	50% strain	70% strain	90% strain
Rigid	23.3	29.0	72.8	123	294
Conformable	12.5	20.8	33.6	54.8	191

Further modify the 10 cm wide conformable panel domain by slicing a 90-95 mm deep slit along the length of the panel

domain, generally in the center of the width dimension, using a hot blade.

Create a testing cavity by placing two studs parallel to each other and a specified distance apart, with a major planar surface of one stud facing a major planar surface of the other stud. The volume between the two studs defines the cavity with the stud spacing defining the cavity width. The surface of each stud has a width (defining the depth of the cavity) of greater than 10 cm. Tilt the studs so that the cavity is at a 45 degree angle, relative to horizontal, to simulate a roof pitch.

Place a cylindrical object of a specified diameter along the major planar surfaces of a stud. The object simulates, for example, a cable, conduit, or pipe along a stud or joist.

Place either Ex 1 or Ex 2 into the cavity by first bending the building panel along the slit in the 10 cm wide conformable band, inserting the panel edges into the cavity and against the stud surfaces, and then pressing along the slit until the building panel is fully inside the cavity (*see*, for example, FIGs 2a and 2b). Both Ex 1 and 2 tightly fit into the cavity without buckling when the stud spacing is between 60 cm and 56 cm. Buckling occurs in the building panel when the spacing is less than 56 cm, with buckling most evident in the 10 cm wide conformable band.

Ex 1 conforms to a cylindrical object having a diameter of 5 mm or less, forming a tight seal with the stud. Ex 1 does not form a tight seal around a cylindrical object having a 10 mm diameter or greater.

Ex 2 conforms to a cylindrical object having a 15 mm diameter, forming a tight seal with the stud.

<u>Ex 3: Building Panel Containing a Polyurethane Foam Conformable Panel Domain</u>

Ex 3 illustrates a building panel of the present invention that contains a polyurethane foam conformable panel

domain. Ex 3 further illustrates an advantage of having a conformable edge band for conforming around objects on a cavity wall. Ex 3 has a structure similar to that of the building panel in FIGs 2a and 2b. The panel domains in Ex 3 are examples of bands.

Cut two rigid domains 130 cm long, 20 cm wide and 10 cm thick from a PS foam board, such as STYROFOAM® Roofmate SL polymeric foam insulation (STYROFOAM is a trademark of The Dow Chemical Company). Cut three conformable bands 130 cm long and 10 cm thick, two of them 5 cm wide and one of them 10 cm wide from a flexible polyurethane (PU) foam (such as PU foam 16F from Metzeler Mousse). Adhere the panel domains together using a two-part epoxy adhesive along the 130 cm long and 10 cm thick edges to create a building panel having similar dimensions to Ex 2 and having the following panel domain orientation:

5 cm PU foam/PS foam/10 cm PU foam/PS foam/5 cm PU foam

Table 3 shows the compressive strength profile for the PU foam. For comparison, the compressive strength for the PS foam is 229 kPa at yield.

Table 3. Compressive Strength of Flexible Polyurethane Foam (in kPa)

10% strain	25% strain	50% strain	70% strain	90% strain
5.07	5.47	5.77	8.72	61.96

Insert Ex 3 into the testing cavity using the procedure described in Ex 1 and 2. Ex 3 fits into cavities having a spacing from 60 cm to 56 cm without buckling and tightly conforms around a cylindrical object having a 15 mm diameter on a major planar surface of the cavity wall.

Ex 4. Polyurethane Building Panel

Make a building panel as described for Ex 3 except use a rigid polyurethane foam instead of a PS foam. The rigid polyurethane foam has a density of 35 kg/m^3, according to EN1602, a compressive strength of 146 kPa at yield, and a thermal conductivity of 19 milliwatts per meter-Kelvin (mW/m*K).

Ex 4 performs similarly to Ex 3 and further illustrates a building panel of the present invention comprised of polyurethane foam. The thermal conductivity of the hard polyurethane foam makes this a particularly attractive thermally insulating building panel.

Ex 5. Rock Wool Building Panel

Ex 5 illustrates an all-fiber building panel of the present invention.

Cut a piece of rock wool having a density of 55 kg/m^3 (such as ROCKPLUS™ insulation, ROCKPLUS is a trademark of Rockwool) into a panel 130 cm long, 60 cm wide, and 10 cm thick. Compress a 10 cm wide conformable band the full 130 cm length through the center of the panel to 20% of its original thickness using either a roller or a hydraulic press. Compressing the panel elastifies the rock wool structure, creating a conformable domain. The panel assumes a rigid band/conformable band/rigid band configuration. This panel is Ex 5.

Table 4 shows the compressive strengths of the non-compressed (rigid) bands and the compressed (conformable) band.

Table 4. Compressive strength in kPa for compressed and non-compressed bands in Ex 5.

Panel Domain	5% Strain	10% strain	25% strain	50% strain
Non-Compressed (rigid)	2.5	5.2	9.9	18
Compressed (conformable)	1.1	1.4	2.9	16

Ex 5 securely fits with a cavity spacing of 57 cm using the cavity wall test apparatus from Ex 1.